

MQ-9 *Ikhana*

UAS-NAS Project Status:

- 1. FAA Pilot Training**
- 2. ADS-B Flight Tests**



Mark Pestana

Project Pilot

UAS-Integration-in-the-NAS

HSI & IT&E

NASA Dryden Flight Research Center

FAA UAS Pilot Training



Introductory NASA MQ-9 *Ikhana* (Predator-B) UAS Flight Operations Course



FAA Pilot Training: Purpose & Rationale

- **FAA Request** : Need for Aviation Safety Inspector (ASI) pilots to gain experience in UAS operations. Five ASIs attended the course.
 - Also included maintenance inspector.
- **Utilize NASA UAS experience**
 - Over 60-year history includes extensive RPV / UAV research flights.
 - Current UAS: MQ-9 Pred-B; RQ-4 Global Hawk, DROID SUAS (and X-48 support)
 - MQ-9 Predator-B (*Ikhana*) flown since 2007.
 - NASA developed standards for pilot training, qualification, currency.
 - Developed procedures and risk mitigation for simultaneous manned and UAS flight ops at Edwards AFB (airfield and airspace operations).
 - Extensive collaboration with FAA in COA development, hazard analyses/risk mitigation, and flight operations in the National Airspace System.
 - NASA- USFS Western States Fire Mission flown during wildfire seasons, 2007-2009.
 - U.S. Army TRACER missions flown 2010-2011 to/from Yuma, AZ, test range.



Training Plan

- Curriculum based on *General Atomics ASI* and USAF: adapted for NASA use.
- “Introductory” Curriculum previously developed and approved by NASA and USAF.
 - 2011: NASA DFRC provided first MQ-9 training for the USAF Test Pilot School.
- **NASA FAA Training Plan: 5-day introductory course; 07-11 May 2012.**
 - **1. Intro to UAS / MQ-9:** Tours of aircraft, GCS, and data-link systems. Controls, Landing gear
 - **2. Systems:** Fuel, Engine, Prop, Electrical, Lighting. Flight manual/checklist review.
 - **3. Systems:** Air data, Flight computers, Autopilot, Data-link, radios. Simulator sessions.
 - **4. Local Operations,** Limitations, EPs, Performance. Simulator sessions. Tech Brief to management.
 - **5.** Pre-flight brief, **Flight Demonstration**, Debrief, Forward planning.
- **Desktop Simulator: Part Task Trainer.**
 - Utilized for “hands-on” takeoff and landing, handling qualities and input response (including Ku latency).



Training Plan (cont.)

- **Flight demonstration conducted on 11 May 2012**
 - 2.4 hours total flight time, within Edwards AFB restricted airspace R-2515, C-Band Line-of-Sight C² only.
 - NASA pilots performed pre-flight checks, engine start, taxi, takeoff, climb, descent, landing.
 - Each FAA pilot flew about 0.4 hour: During “cruise” flight. With and without Autopilot engaged.
 - Autopilot engaged: Waypoint/flight plan generation/modification, navigation, lost-link flight planning.
 - “Hands on” flying: Pitch/bank/yaw demo; climbs/descents; input/response demo.
- **Follow-up plans:**
 - Continue training on MQ-9 simulator at FAA Tech Center, Atlantic City, NJ, with NASA DFRC Instructor Pilots.
 - Further collaboration and advising on flight crew standards, maintenance, airworthiness, safety analyses.
- **FAA investigating the utility of a traffic display system in GCS**
 - Planning to visit DFRC, interview UAS pilots, and conduct Part Task Simulations.





Ikhana – UAS-NAS ADS-B/LVC-DE Flight Tests



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Automatic Dependent Surveillance –
Broadcast (ADS-B)
Live Virtual Constructive –
Distributed Environment
Simulation and Flight Tests



LVC-DE Staffing



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- **Dryden Sim Lab**
 - Marlin Pickett
 - Martin Hoffman
 - Chris Howell
 - Jamie Willhite
 - Sam Kim (Alternate)
 - Carl Magnusson (Ikhana Sim Pilot)
- **Ikhana GCS**
 - Sam Kim
 - Martin Hoffman (Alternate)
 - Mark Pestana (Pilot)
 - Hernan Posada (Pilot)
 - David Ewers (SysMon)
 - Kathleen Howell (MD)
 - Ricardo Arteaga
 - Mike Dandachy
- **Ames Sim Lab**
 - Neil Otto
 - Srba Jovic
 - Jeffrey Hernandez
 - George Solar
 - Wayne Bridges
 - Dave Brown
 - Jacob Pfeiffer
 - Riva Canton
 - Jim Murphy



ADS-B Overview



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- **Automatic Dependent Surveillance Broadcast (ADS-B):** ADS-B is an advanced surveillance technology where ADS-B equipped aircraft share position, altitude, velocity, and other information with ATC and other appropriately equipped aircraft
- **ADS-B represents the backbone technology for airspace integration in the Next Generation Air Transportation System (NextGen)**
 - Assess navigation accuracies of the installed ADS-B system
 - Evaluate its suitability for providing separation assurance
- **The MQ-9 represents the UAS employed by several public agencies seeking routine access to the NAS**
- **ADS-B “In” is the reception by properly equipped aircraft of surveillance information**
 - ADS-B “Out” transmissions from nearby aircraft
 - Transmissions from ADS-B Ground Stations that include surveillance radar derived (TIS-B) and re-broadcast of ADS-B data (ADS-R)



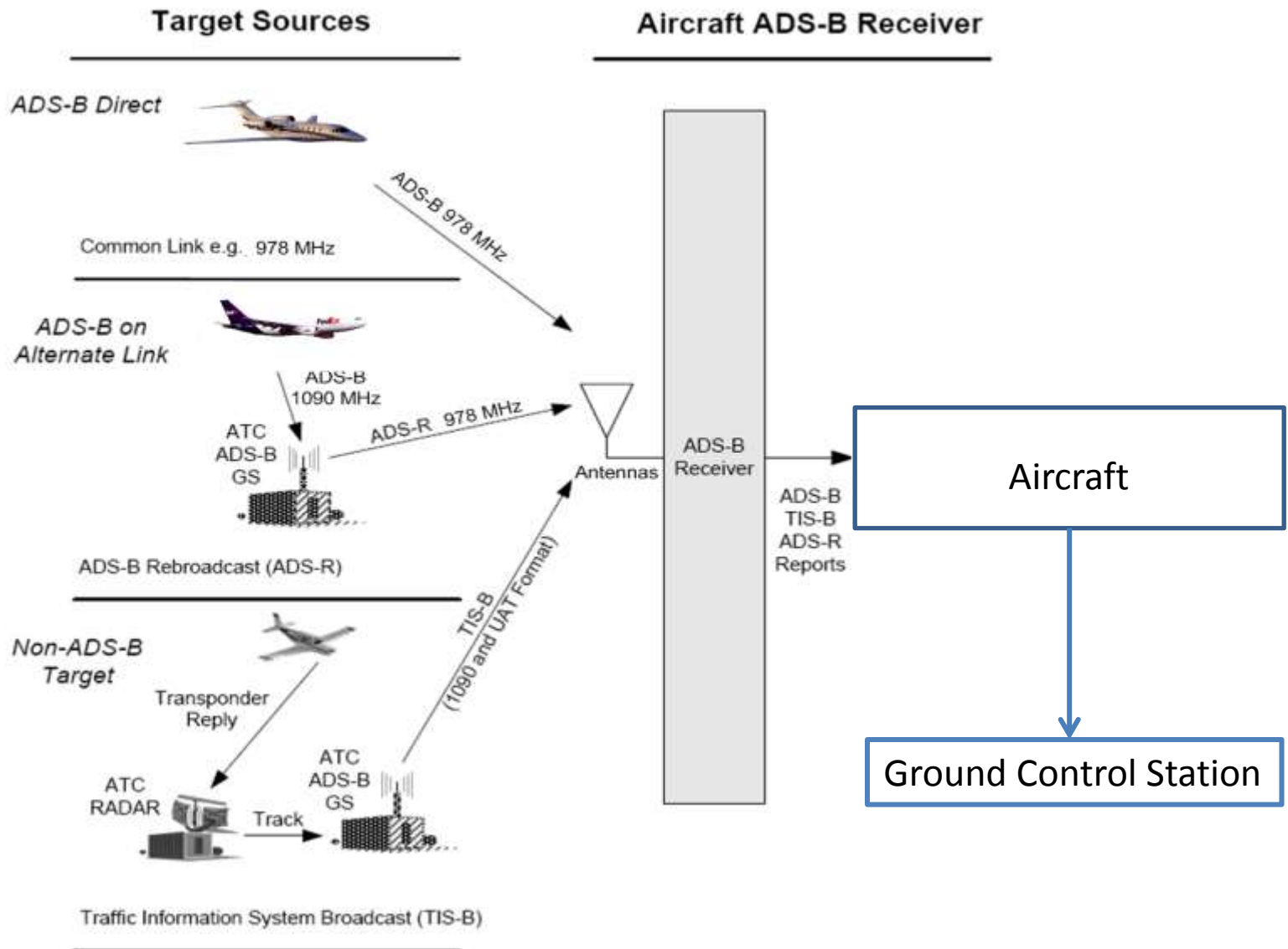
Current ADS-B Ground Stations and Coverage



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ADS-B “In” Architecture Design Overview





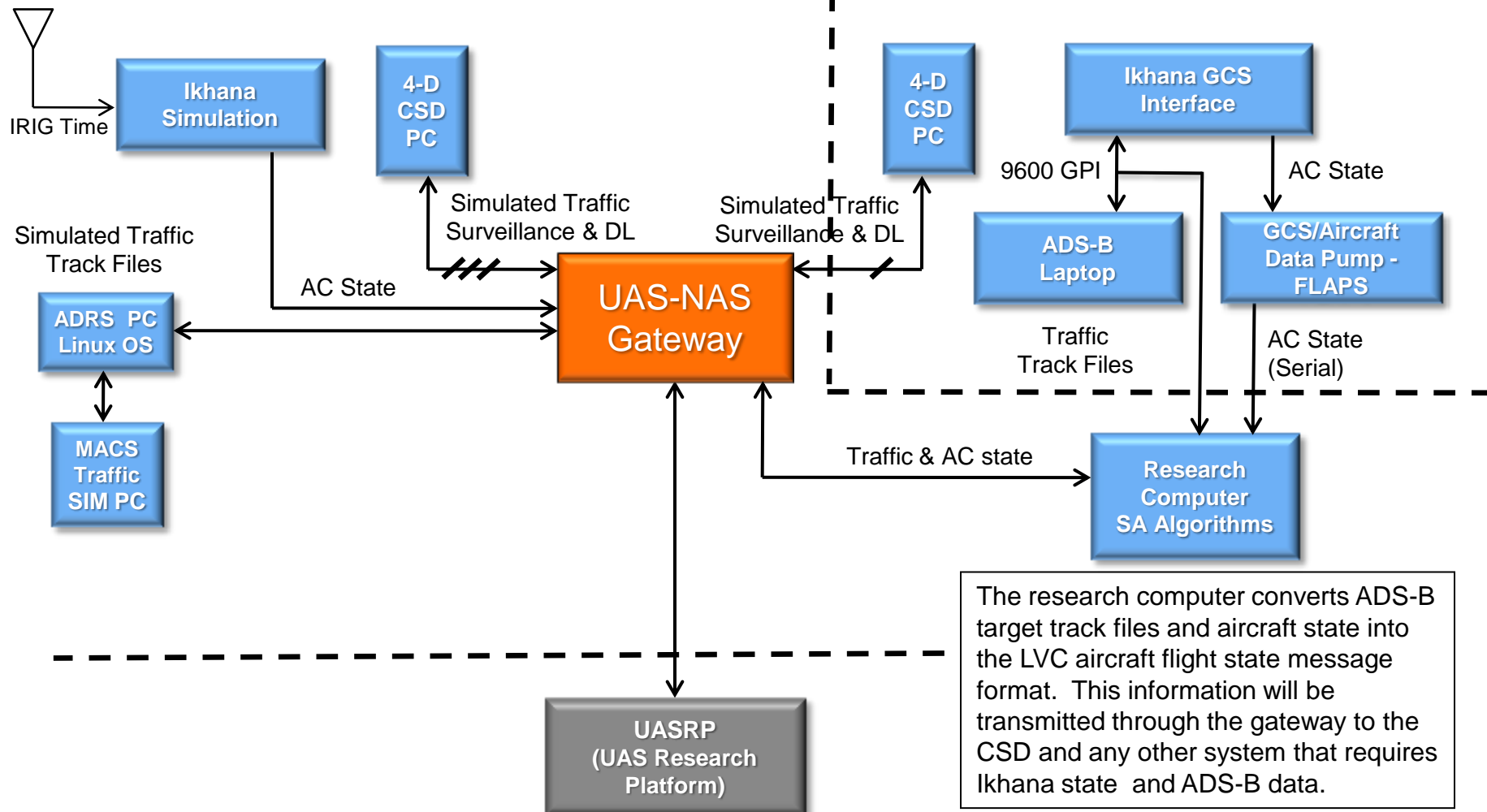
Dryden LVC-DE Logical Interface



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Building 4840 Ikhana Sim Lab

Ikhana GCS





LVC-DE Core Architecture Components

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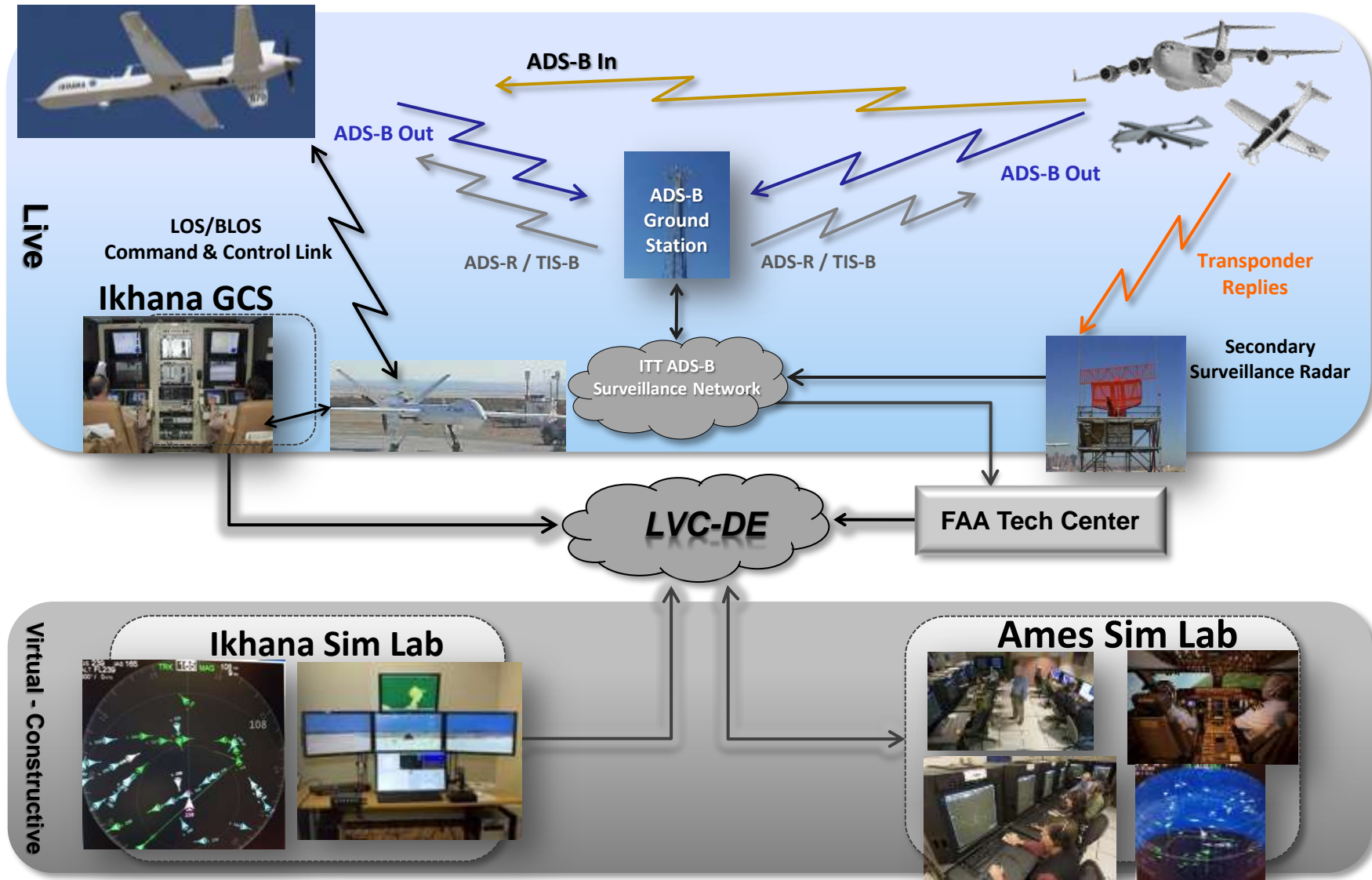
- **DSRL – Distributed Simulation Research Lab (Ames Research Center)**
- **UASRP – UAS Research Platform – DSRL gateway (Ames)**
- **UAS-NAS Gateway – local network gateway to DSRL (DFRC)**
- **MACS – Multi-Aircraft Control System**
 - Constructs aircraft traffic scenario
 - ATC Displays
 - Pseudo pilot control displays for constructive traffic
- **ADRS – Server allows external simulation interface to MACS**
- **CSD – Cockpit Situation Display**
- **Research Computer**
 - Aircraft state data reader software
 - ADS-B aircraft state data reader software
 - Convert & outputs data to UAS-NAS Gateway
- **ADS-B – Automatic Dependent Surveillance-Broadcast**
 - FAA approved airborne data link



Live Virtual Constructive Distributed Environment



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Software Development Tests

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- Performed tests with ADS-B mobile van for software code validation on April 20th
- Ground tests performed on Ikhana using ADS-B System Test and Verification Procedure (Rev F) on April 27th
- Used live ADS-B Ground Radio Station DS 293 (located by Victorville)
- ADS-B “In” functionality verified with real-time aircraft surveillance of TIS-B/ADS-B targets in the EDW’s traffic pattern



Ground Tests



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ADS-B Performance

ADS-B “Out” Requirements

- $NAC_p < 0.05$ nm or value of 8
- $NIC < 0.2$ nm or value of 7
- $SIL = 2$ or 3 or 1×10^{-7}



Ground test results on Ikhana for ADS-B “Out” Performance

- $NAC_p < 10$ m or value of 10
- $NIC < 25$ m or value of 10
- $SIL = 2$ or 1×10^{-5}
- GPS Alt < 150 ft from surveyed reference point

ADS-B “In”

- ADS-B “In” system was able to track up to ten real-time surveillance tracks
- ADS-B mobile van was configured as an F/A-18 target
- Verified the proper reception of ADS-B messages and the correct display of a stationary and moving target



Flight Test Objectives



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Prototype LVC-DE Flight Test Objectives:

- **Demonstrate LVC-DE prototype architecture with Ikhana UAS in flight**
- **Evaluate integration of live flight vehicle**
 - **Multi-Aircraft Control System (MACS) simulation scenario and ATC displays**
 - **Cockpit Situation Display (CSD)**
 - **ADS-B “In” traffic report processing and display**
 - **Identify UAS and simulation timing issues**
 - **Support future mission planning scenarios**



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More Bang for the Buck!

*Additional Test Points Requested by LaRC**

- Altitude
- Vertical velocity
- Body axis angular rates
- Angle of attack
- Angle of sideslip
- Airspeed
 - Calibrated
 - True
- Ground track angle
- Wind speed and direction
- Control surface deflections
- Time of command execution
- Commanded heading
- Commanded speed
- Commanded altitude or altitude change
- Commanded vertical rate
- From 5000' MSL to FL400 (in 5k' increments)
 - 90° heading change airspeed of 90 knots
 - 90° heading change airspeed of 140 knots
 - 90° heading change airspeed of 200 knots
 - From 90 knots, 140 knot, and 200 knots
 - 2000 foot climb at 500 ft/min
 - 2000 foot descent at 500 ft/min
 - 2000 foot climb at 1000 ft/min
 - 2000 foot descent at 1000 ft/min
 - 2000 foot climb at 2000 ft/min
 - 2000 foot descent at 2000 ft/min
 - 1000 ft/min climb/descent.
 - 2000 ft climb at maximum throttle
 - 2000 ft descent at idle
 - 2000 ft climb at “typical” rate

*** Subset of this was performed. Provided performance data for further modeling**

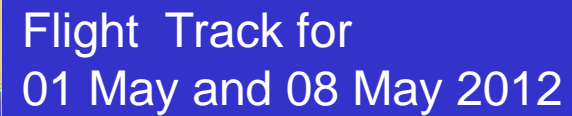


UAS-NAS LVC Project Overview



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- ADS-B In – Demonstrate the acquisition of ADS-B traffic information (via GDL-90) and the ADS-B display in the Ikhana GCS. (Not used by aircrew during this test.)
- LVC-DE Sim – Demonstrate the acquisition of ADS-B In information (via FLAPS / SRFN) and its distribution to its Cockpit Situation Displays (CSD) located in the Ikhana GCS, the DFRC Simulation Lab and to the ARC Simulation Lab.
- Two “Stand-alone” Test Flights: 15 Mar (2.7 hrs), 20 Mar (2.5 hrs)
 - Ikhana/ADS-B “OUT” Functional Checks
- **Two Integrated LVC Test Flights**
 - 01 May 2012: 0.9 hour
 - 08 May 2012: 1.7 hours
- One “non-interference” flight
 - 11 May 2012: 0.9 hour, FAA Pilot Training Flight



15 March 2012 Flight Track





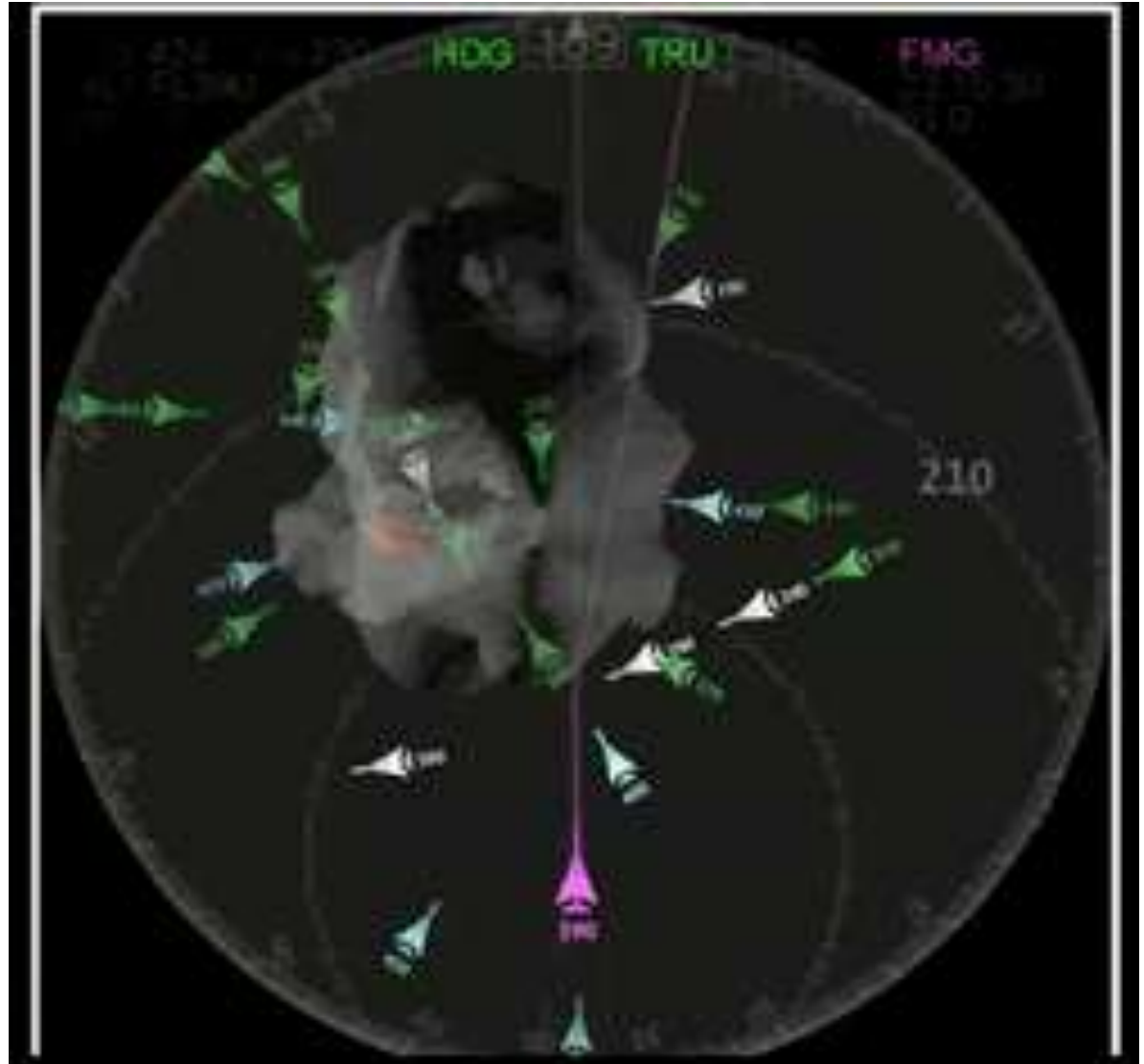
This display is a “repeater” from the ATC Radar Facilities. This display is typically utilized by Range Safety Officers for situational awareness and safety advisory.

The screenshot shows a radar plot with various balloons and a list of Balloon Data Assignments. The balloons are labeled with IDs such as R41, C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C57, C58, C59, C60, C61, C62, C63, C64, C65, C66, C67, C68, C69, C70, C71, C72, C73, C74, C75, C76, C77, C78, C79, C80, C81, C82, C83, C84, C85, C86, C87, C88, C89, C90, C91, C92, C93, C94, C95, C96, C97, C98, C99, C100. The list of Balloon Data Assignments is as follows:

Balloon Data Assignments
1. EMPTY
2. EMPTY
3. EMPTY
4. EMPTY
5. EMPTY

Aircraft Icons:

- Virtual Traffic
- Real Traffic
- Ikhana
- “Own ship”
(Simulated Ikhana)





Ikhana ADS-B / LVC Flight Test Results



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- **Success!**
- Developed ADS-B “In” and “Out” capability for the Ikhana UAS
- Utilizing the FAA Technical Center’s validated data analysis tools, the analysis showed the ADS-B performance to **exceed FAA requirements.**
- Completed a full systems integration test of the Live Virtual Constructive – Distributed Environment (LVC-DE) between Dryden and Ames
- Cockpit Situation Display aided Sim Pilot in SA and maneuvering.
- Performance data acquired for LaRC modeling
- **Forward Plans:**
- **June-July:** Continue LVC development (full FAA surveillance data connectivity)
- **Aug-Sep:** Develop Research GCS (RGCS) and integrate into the LVC-DE network
- **Aug-Oct:** Modify the TG-14 into a UAS Surrogate, equip with ADS-B, and integrate command and control with the RGCS
- **FY 2013 - :** Re-integrate ADS-B system back onto the Ikhana UAS upon completion of its Block 1 upgrade
- Perform ADS-B and LVC flight tests with the TG-14 UAS Surrogate
- Global Hawk to be equipped with ADS-B: Evaluate navigational accuracy (FL600+) for the FAA